Dec. 6, 1966 J. T. HAINES 3,289,428

REVERSE CYCLE REFRIGERATION SYSTEM

Filed April 6, 1965 2 Sheets-Sheet 1

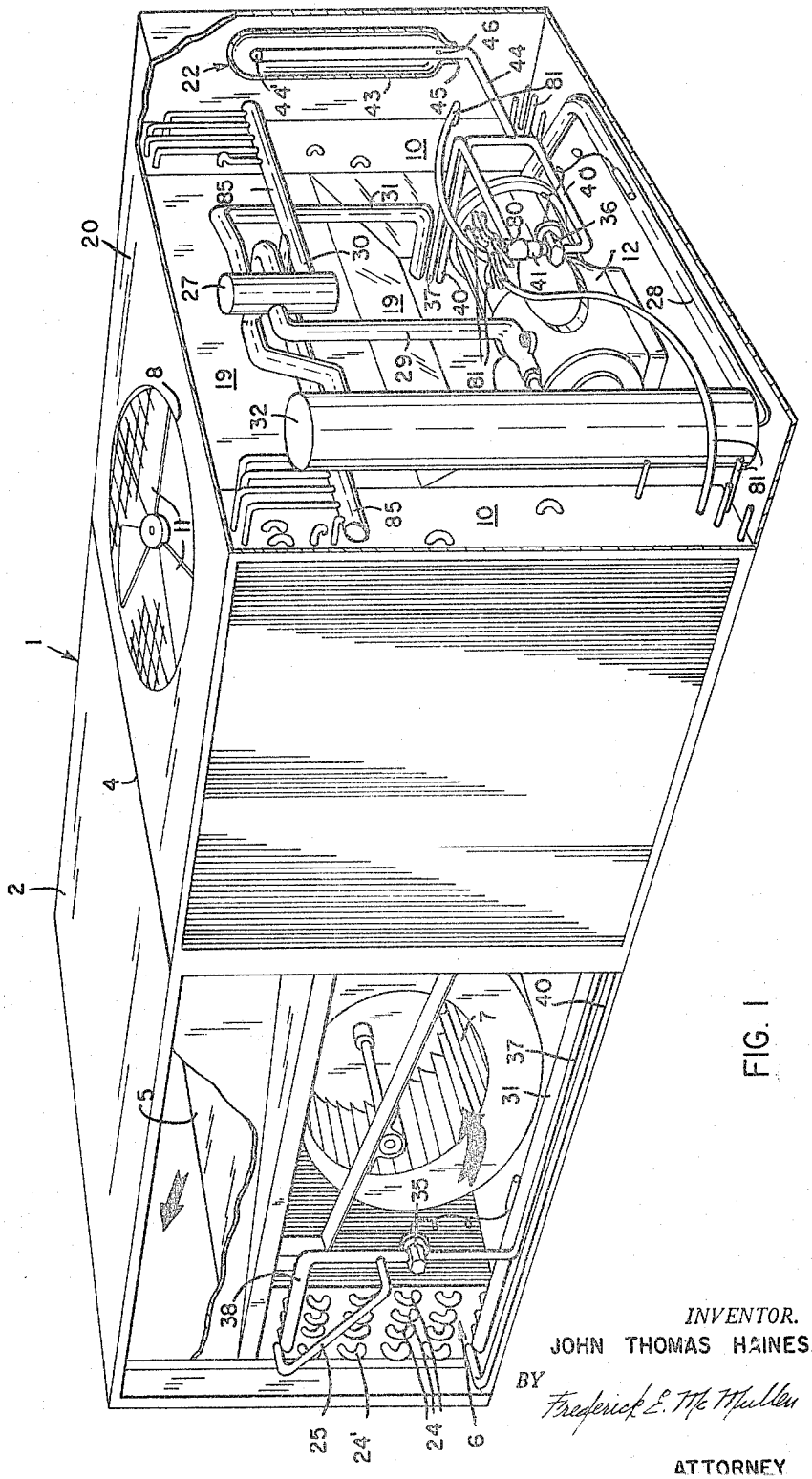


FIG. 1

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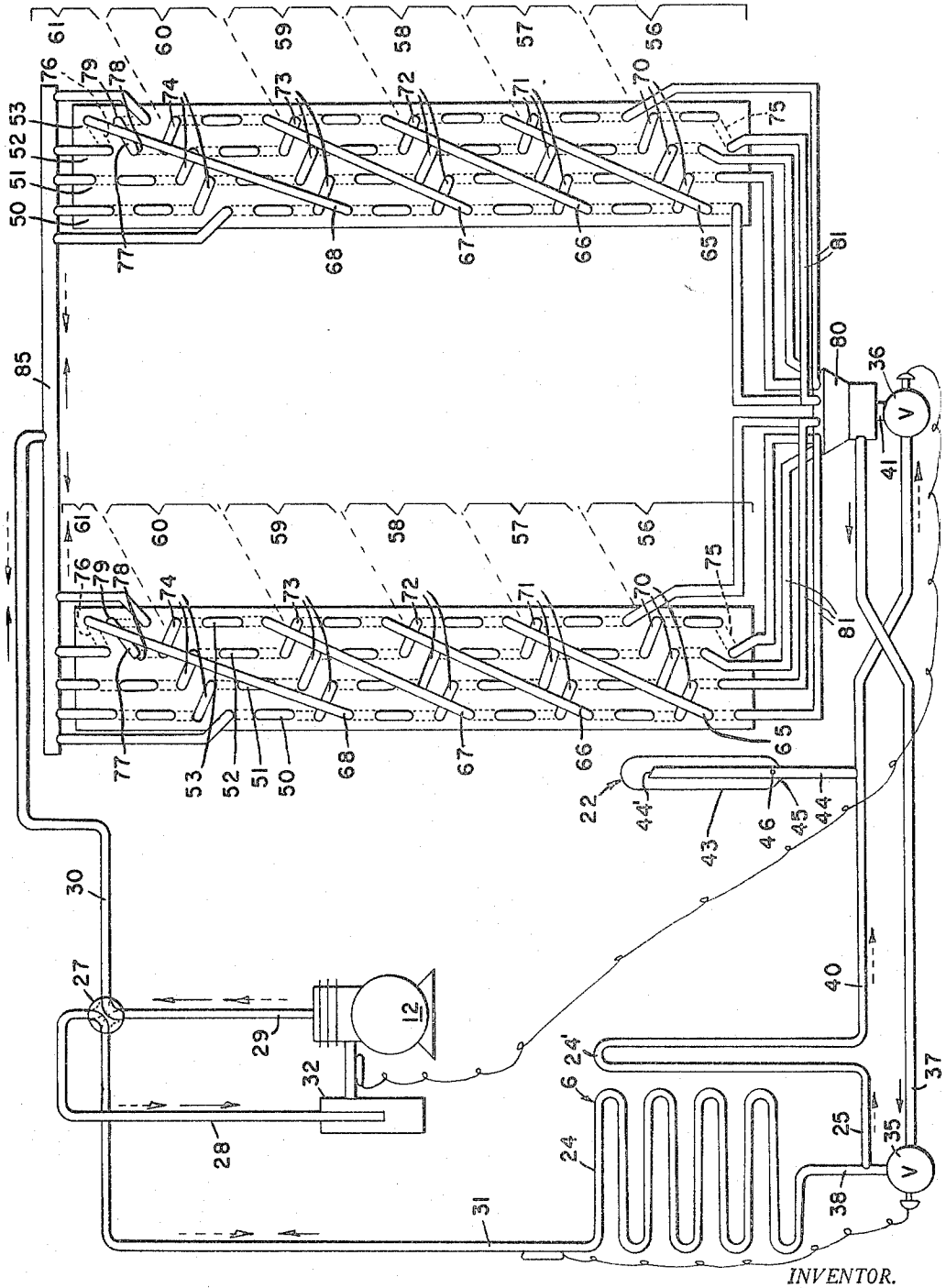


FIG. 2

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3,289,428

REVERSE CYCLE REFRIGERATION SYSTEM

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This invention relates to air conditioning apparatus, more particularly, to an air conditioning apparatus of the reverse cycle type having an improved refrigeration circuit.

In reverse cycle refrigeration systems, a bypass line with check valve is normally employed to bypass refrigerant around the outdoor coil expansion means during cooling cycle operation and around the indoor coil expansion means during heating cycle operation. Each check valve involves added system expense, as well as a source of potential trouble and service.

The quantity of refrigerant needed for efficient operation of the reverse cycle refrigeration system on the heating cycle is normally less than that needed during cooling cycle operation. Excessive refrigerant in the system reduces efficiency. Although arrangements which vary the quantity of refrigerant available to the system from cycle-to-cycle have heretofore been proposed, there has still remained the need for an effective, economical and trouble-free arrangement for regulating the quantity of refrigerant in response to changes in system operating conditions.

Where the refrigeration system is of the reverse cycle type, defrosting of the outdoor heat exchanger coil may be effected by temporarily reverting the system to cooling cycle operation. Where the outdoor heat exchanger coil employed is comprised of a multiplicity of rows of heat exchanger tubing, the gaseous refrigerant discharged from the compressor is usually directed into the upper portion of the outdoor coil during the defrost cycle. Condensed refrigerant leaves the lower portion of the coil. Where the heat exchanger coil is comprised of a relatively few rows of heat exchange tubing, the amount of condensed refrigerant in the lower portions of the coil often becomes excessive, particularly at low outdoor temperatures, and may materially reduce the effectiveness of the defrost cycle in removing frost and ice from the coil.

It is a principal object of the present invention to provide a new and improved reverse cycle refrigeration system.

It is a further object of the present invention to provide an improved reverse cycle refrigeration system incorporating an arrangement for varying the quantity of refrigerant in the system from cycle-to-cycle.

It is an object of the present invention to provide a reverse cycle refrigeration system without check valve bypass means for the system expansion means and which includes an arrangement for changing the quantity of refrigerant utilized by the system from cycle-to-cycle.

It is an object of the present invention to provide a unique heat exchange coil circuiting arrangement effective to reduce the internal flow resistance of the coil.

It is an additional object of the present invention to provide an outdoor heat exchanger coil circuit which effectively transforms a nominal four row four path heat exchanger coil into a five path heat exchanger coil. Other objects will be apparent from the ensuing description and drawings.

This invention relates to a reverse cycle refrigeration system comprising in combination a compressor, an outdoor coil and an indoor coil with a reversing valve effective when in a first position to connect the indoor and outdoor coils to the compressor, suction and discharge sides respectively, and in a second position to connect the indoor and outdoor coils to the compressor discharge and suction sides respectively; a first refrigerant conduit between the indoor coil and the outdoor coil, the first conduit including first refrigerant expansion means; a second refrigerant conduit between the indoor coil and the outdoor coil, the second conduit including second refrigerant expansion means; means for varying the amount of refrigerant in the system in response to system operating conditions including a closed vessel for storing refrigerant and a conduit connecting the vessel with the first conduit between the indoor coil and the first expansion means; the outdoor coil means comprising a plurality of heat exchanger tubes placed in at least two rows, tubes in each of the rows being included in separate circuits through the coil; and crossover means serially connecting tubes in one row to tubes in another row to form at least three refrigerant paths extending throughout the length of the coil.

The present invention will be more fully understood by reference to the following description read in conjunction with the accompanying drawing herein, in which:

FIGURE 1 is a perspective view with parts broken away of the air conditioning apparatus of the present invention; and

FIGURE 2 is a diagrammatic view of the refrigeration circuit of the air conditioning apparatus shown in FIGURE 1.

Referring to FIGURE 1 of the drawing, there is shown an air-to-air type heat pump unit 1 incorporating a refrigerating system operable on the reverse cycle principle to heat or cool. In apparatus of this type, first or indoor heat exchange means is disposed within or in communication with the area to be conditioned, while second or outdoor heat exchange means is located within or in communication with the area outside the area being conditioned, normally the outdoors.

Unit 1 includes a suitable housing 2 separated by a partition member 4 into an indoor compartment encasing indoor coil 6 and fan 7, and an outdoor compartment encasing outdoor coils 10, fan 11 and compressor 12. Fan 7 draws air to be conditioned through indoor coil 6, the conditioned air passing through discharge plenum 5 into the area being conditioned.

A partition or cover 19 cooperates with housing 2 to separate compressor 12 and refrigerant storage means 22 from outdoor coils 10 and fan 11. The fan 11 draws outdoor air through coils 10, the air discharging through opening 8 in wall 20 of housing 2 into the ambient.

Referring to FIGURES 1 and 2, indoor heat exchanger coil 6 is preferably comprised of rows 24 of heat exchange tubes. The row 24' functions as a subcooler as will be more apparent hereinafter. Refrigerant line 25 serially connects rows 24 with row 24'.

Reversing valve 27, which may be any suitable commercially available type, is connected by refrigerant lines 28, 29 to the suction and discharge sides of compressor 12. Refrigerant lines 30, 31 connect reversing valve 27 with outdoor coils 10 and rows 24 of indoor coil 6. Line 28 is preferably provided with a suitable refrigerant accumulator 32.

A pair of suitable thermal type expansion valves 35, 36 are provided. Preferably, valves 35, 36 are of the type whose response mechanism employs a pressure limiting type of charge. Refrigerant lines 37, 38 connect expansion valve 35 between outdoor coils 10 and line 25. Refrigerant lines 40, 41 connect expansion valve 36 between subcooler row 24' of indoor coil 6 and outdoor coils 10.

Refrigerant storage means 22 comprises a closed container 43 having a single opening 45 in the bottom thereof. Refrigerant line 44 connects container 43 with line 40 via opening 45. The open terminal end 44' of line 44 protrudes upwardly within container 43. A small orifice 46 is provided in line 44 adjacent the bottom of container 43.

Referring to FIGURE 2 of the drawings, outdoor heat exchange coils 10 are each comprised of a number of substantially vertical rows of heat exchange tubes 50, 51, 52, 53. While four rows of heat exchange tubes are shown, it is understood that the number of rows of heat exchange tubes may be varied to suit individual applications.

Rows 50, 51, 52, 53 are each separated into a plurality of sections 56, 57, 58, 59, 60, 61 arranged so that when certain of the sections are coupled together in the manner described hereinbelow, plural paths for refrigerant flow are formed. As will be more apparent, the number of refrigerant paths formed is one more than the number of nominal rows of heat exchange tubes. For example, in the coil illustrated in FIGURE 2 a total of five individual refrigerant flow paths are formed in a heat exchange coil consisting of four rows of heat exchange tubes 50, 51, 52, 53.

Crossovers 65, 66, 67 serially connect the uppermost portion of sections 56, 57, 58 of row 50 with the lowermost portion of sections 58, 59, 60 of row 53. Crossovers 70, 71, 72, 73, 74 serially connect the uppermost portion of sections 56, 57, 58, 59, 60 of rows 51, 52, 53 with the lowermost portion of sections 57, 58, 59, 60, 61 of rows 50, 51, 52. Crossover 68 serially interconnects the uppermost portion of section 59 with row 53. Crossover 75 interconnects the lower tubes of rows 52, 53. Crossover 76 interconnects the upper tubes of rows 52, 53, while crossover 77 interconnects tubes 78, 79 of rows 52, 53 respectively.

Line 37 is provided with a suitable refrigerant distribution mechanism 80 coupled by means of individual lines 81 with the lower portions of sections 56 of rows 50, 51, 52 and sections 56, 57 of row 53. The upper portion of sections 60, 61 of row 50, section 61 of row 51, the upper tube of row 52 and the lower portion of section 61 of row 53 are coupled by header 85 with line 30 leading to reversing valve 27.

By the construction described above, outdoor heat exchange coils 10, each comprising a nominal four rows of heat exchange tubes, are transformed into five individual paths as follows:

Path #1: Sections 56, 58, 59, 60, 61 of rows 50, 53, 52, 51 and 50 respectively.

Path #2: Sections 56, 57, 59, 60, 61 of rows 51, 50, 53, 52, 51.

Path #3: Sections 56, 57, 58, 60, 61 of rows 52, 51 50, 53, 52, 53.

Path #4: Crossover 75, and sections 56, 57, 58, 59 of rows 53, 52, 51, 50, and crossovers 68 and 76.

Path #5: Sections 57, 58, 59, 60, of rows 53, 52, 51, 50.

By the coil circuiting arrangement proposed, an additional refrigerant path is formed in each coil 10. Each path of heat exchange tubes has substantially equal heat transfer ability. With respect to the heat transfer ability of the several individual refrigerant paths formed, it may be noted that the difference in temperatures between that of the outdoor air flowing through coils 10 and the refrigerant passing through the heat exchange tubes of coils 10 decreases as the outdoor air travels through the coils, the temperature differential normally being greatest at the point of entry of the air and least at the point of air discharged. Each path includes substantially equivalent sections from each row 50, 51, 52, 53 thereby accommodating changes in temperature differential between outdoor air and the refrigerant flowing through the coils. In this way, the several refrigerant paths formed are substantially balanced. By increasing the number of refrigerant paths, the internal resistance of coils 10 is decreased. During cooling and defrost cycles, the increased number of refrigerant paths reduces the level of condensed refrigerant in the heat exchanger coil.

During cooling cycle operation, reversing valve 27 is in the position shown in solid lines of the drawing. Upon a demand for cooling the drive motor to compressor 12 (not shown) and the respective drive motors for indoor and outdoor fans 7, 11 (not shown) are energized.

Relatively high pressure gaseous refrigerant discharged by compressor 12 through line 29 is routed by reversing valve 27 through line 30 and header 85 into outdoor coils 10 where ambient air under the influence of fan 11 extracts heat therefrom. Refrigerant from coils 10 passes through lines 81 into distributor 80 and through line 37, expansion valve 35 and line 38 into rows 24 of indoor coil 6. Expansion valve 35 throttles or expands the refrigerant to a lower pressure in response to conditions of the refrigerant leaving coil 6 as is understood by those skilled in the art. Refrigerant in rows 24 of indoor coil 6 extracts heat from the indoor fan air stream flowing therethrough, the cooled air then flowing into the area being conditioned. Refrigerant from indoor coil 6 returns through line 31, reversing valve 27 line 28 and accumulator 32 to compressor 12 to complete the refrigeration circuit.

To initiate heating cycle operation, reversing valve 27 is moved by suitable means (not shown) to the dotted line position shown in the drawing to route the relatively hot gaseous refrigerant from compressor 12 through line 31 and rows 24 of indoor coil 6. The indoor fan air stream is heated by the refrigerant in coil 6, the heated air flowing into the area being conditioned. The condensed refrigerant flows through line 25 into subcooler row 24' where further heat exchange is effected between the indoor fan air stream and the refrigerant. The refrigerant from row 24' passes through line 40, expansion valve 36 and line 41 into distributor 80 and through distributor lines 81 into outdoor coils 10. Valve 36 serves to expand or throttle the refrigerant to a lower pressure in response to conditions of the refrigerant leaving coils 10. Refrigerant flowing through coils 10 extracts heat from the outdoor air stream drawn therethrough by fan 7. The refrigerant returns through header 85 and line 30 to reversing valve 27 and compressor 12.

It is understood that expansion valves 35, 36 close during heating and cooling cycles respectively. Thus, during cooling cycle operation, valve 36 closes line 40 to the flow of refrigerant from coils 10. Similarly, during heating cycle operation, valve 35 closes line 37 to the flow of refrigerant from indoor coil 6.

The amount of refrigerant required for cooling cycle operation is normally greater than the amount of refrigerant needed for heating cycle operation. Refrigerant storage means 22 varies the amount of refrigerant in the system by adding or withdrawing refrigerant to or from the circuit.

During cooling cycle operation, line 40, and line 44 which connects container 43 with the system, are at system low side pressure since expansion valve 36 is closed to the flow of high pressure refrigerant from outdoor coil 10. Container 43 is disposed outdoors separated from outdoor coils 10 by partition 19. The temperature to which container 43 is exposed is normally slightly different than outdoor temperature. During cooling cycle operation, outdoor temperatures, and accordingly the temperature circumjacent container 43, are relatively high. The combination of a relatively warm container 43 and relatively low system pressures drives refrigerant from container 43 through line 44 into the refrigeration system.

During heating cycle operation, refrigerant pressures in line 40 are relatively high. Temperatures circumjacent container 43 are relatively low. The combination of a relatively cool container 43 and relatively high system

pressures tends to draw refrigerant from the system through line **44** into container **43**.

As may be understood, the quantity of refrigerant in container **43** at any single time varies with container temperature and refrigerant system pressures. Orifice **46** facilitates return of oil trapped in container **43** to the refrigeration system and compressor **12**.

By the present invention, applicant has provided an improved refrigeration circuit for reverse cycle refrigeration systems in which check valve controlled bypass means for the system expansion devices are omitted. Applicant's circuiting arrangement enhances the efficiency of the outdoor heat exchange coil during both heating and cooling cycle operation. And, applicant's improved refrigeration circuit incorporates means for varying the amount of refrigerant available to the system in response to system operating conditions.

While I have described a preferred embodiment of the present invention, it is understood that this invention may be otherwise embodied within the scope of the following claims.

I claim:

1. In a reverse cycle refrigeration system, the combination of a compressor, an outdoor coil, an indoor coil, and a reversing valve, effective when in a first position to connect the indoor and outdoor coils to the compressor suction and discharge sides respectively, and when in a second position to connect the indoor and outdoor coils to the compressor discharge and suction sides respectively, a first refrigerant conduit between said indoor coil and said outdoor coil, said first conduit including first refrigerant expansion means, a second refrigerant conduit between said indoor coil and said outdoor coil, said second conduit including second refrigerant expansion means, means for varying the amount of refrigerant in said system in response to system operating conditions including a closed vessel for storing refrigerant and a conduit connecting said vessel with said first conduit at a point between said indoor coil and said first expansion means, said outdoor coil comprising a plurality of heat exchange tubes placed in at least two substantially parallel rows, tubes in each of said rows being included in separate circuits through said coil, and crossover means serially connecting tubes in one row with tubes in another row to form at least three refrigerant paths extending throughout the length of the coil.

2. In a reverse cycle refrigeration system having a compressor, an outdoor coil, first and second serially connected indoor coils, and valve means effective when in a first position to route refrigerant from said first indoor coil through the compressor to said outdoor coil and in a second position to route refrigerant from said outdoor coil through the compressor to said first indoor coil; the combination of; first expansion means connected between said outdoor coil and said first indoor coil effective upon positioning of said valve means in said first position to expand relatively high pressure refrigerant discharged from the outdoor coil into the first indoor coil, second expansion means connected between said second indoor coil and said outdoor coil effective upon positioning of said valve means in said second position to expand relatively high pressure refrigerant discharged from the second indoor coil into said outdoor coil, said first expansion means preventing flow of refrigerant from said first indoor coil directly to said outdoor coil; and means for varying the amount of refrigerant in said system in response to changes in system operating conditions including a closed vessel, and a conduit connecting said vessel with said system at a point between said second expansion means and said second indoor coil.

3. In an apparatus having reverse cycle refrigeration system including first and second series connected indoor heat exchange coils, an outdoor heat exchange coil and a compressor having suction and discharge sides, with a reversing valve selectively operable to connect the compressor discharge and suction sides with said outdoor coil and said first indoor coil during cooling cycle operation and to connect said compressor discharge and suction sides with said first indoor coil and said outdoor coil during heating cycle operation, the combination of first and second thermal expansion valves, first refrigerant line connecting the input side of said first thermal expansion valve with said outdoor coil, a second refrigerant line connecting the output side of said first thermal expansion valve at a point between said first indoor coil and said second indoor coils, a third refrigerant line connecting the input side of said second thermal expansion valve with said second indoor coil, a fourth refrigerant line connecting the output side of second thermal expansion valve with said first refrigerant line, refrigerant storage means, and a fifth refrigerant line connecting said storage means with said third refrigerant line.

4. The apparatus according to claim **3** including a housing, first partition means separating said housing into an indoor compartment encasing said first and second indoor coils and an outdoor compartment encasing said outdoor coil, compressor, and refrigerant storage means, and second partitioning means in said housing outdoor compartment separating said outdoor coil from said refrigerant storage means.

5. In a heat exchanger, the combination of: a plurality of heat exchange tubes disposed in at least four rows, tubes in each of said rows being arranged into at least five individual sections; first crossover means serially interconnecting a first section first row, third section fourth row, fourth section third row, and fifth section second row respectively to form a first path for refrigerant extending throughout the length of said heat exchanger; second crossover means serially interconnecting a first section second row, second section first row, fourth section fourth row, and fifth section third row respectively to form a second path for refrigerant extending throughout the length of said heat exchanger; third crossover means serially interconnecting first section third row, second section row, third section first row, and fifth section fourth row respectively to form a third path for refrigerant extending throughout the length of said heat exchanger; fourth crossover means serially interconnecting first section fourth row, second section third row, third section second row, and fourth section first row respectively to form a fourth path for refrigerant extending throughout the length of said heat exchanger; and fifth crossover means serially interconnecting second section fourth row, third section third row, fourth section second row and fifth section first row respectively to form a fifth path for refrigerant extending throughout the length of said heat exchanger.

6. Coil apparatus according to claim **5** in which said rows of heat exchanger tubing are substantially vertical.

7. In a heat exchanger, the combination of: a plurality of heat exchanger tubes disposed in at least three rows, tubes in each of said rows being arranged in at least four individual sections; first crossover means serially interconnecting a first section first row, third section third row and fourth section second row respectively to form a first path for refrigerant extending throughout the length of the heat exchanger; second crossover means serially interconnecting a first section second row, scond section first row and fourth section third row respectively to form a second path for refrigerant extending throughout the length of said heat exchanger; third crossover means serially interconnecting a first section third row, second section second row and third section first row respectively to form a third path for refrigerant extending throughout the length of said heat exchanger; and fourth crossover means serially interconnecting a second section third row, third section second row and fourth section first row respectively to form

a fourth path for refrigerant extending throughout the length of said heat exchanger.

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